# Litter decomposition studies using mesh bags: spillage inaccuracies and the effects of repeated artificial drying

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A modified method of measuring litter decomposition using mesh bags is suggested in which the bags are reused during several time increments. The chief objections to this method are that litter may be lost through spillage and that repeated artificial drying may affect decomposition rates. Experimental results are presented to show that spillage represents a significant source of error with finely divided litter, even using conventional litter bag methods. A method for handling litter bags is suggested in which corrections may be made for spillage. In a second experiment it was found that decomposition rates were not significantly altered by repeated artificial drying of old-field litter so that repeated drying of litter in field experiments may be valid.

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Les auteurs proposent une méthode modifiée de mesurer la décomposition des litières dans des sacs à mailles; cette méthode permet de réutiliser les mêmes sacs pendant plusieurs intervalles. Les objections majeures à cette méthode sont les pertes possibles de litière et aussi le fait que la dessication artificielle répétée puisse affecter les taux de décomposition. Les résultats expérimentaux obtenus montrent que la perte de litière représente une source d'erreur significative avec une litière finement divisée, même en utilisant la méthode conventionnelle. Les auteurs proposent une façon de manipuler les sacs de litière qui permet d'effectuer des corrections pour les pertes. Une deuxième expérience a démontré que les taux de décomposition ne sont pas modifiés de façon significative par des séchages artificiels répétés de litière provenant de champs abandonnés, de sorte que la dessication répétée de litière dans des expériences aux champs peut être valide. [Traduit par le journal]

## Introduction

In litter decomposition studies it is possible to measure litter input and disappearance by indirect methods (Wiegart and Evans 1964; Lomnicki *et al.* 1968). Most workers, however, have attempted to maintain the physical and chemical identity of the material under study by confining it in a variety of ways (Falconer *et al.* 1933; Lunt 1935; Nommick 1938; Wittich 1939; Gustafson 1943; Mikola 1955). The use of synthetic netting materials to confine litter (Gilbert and Bocock 1958, 1962) has become common practice in recent years (Maldague 1967; Gessner and Goos 1972; Witkamp 1966; Edwards and Heath 1963).

In decomposition studies involving litter bags three techniques are available (Fig. 1).

(1) A large number of litter bags is placed at a given point at the start of the experiment and a randomly chosen sample is dried and weighed at the end of each time period.

(2) A set of bags is placed in the field at the start of each measurement period and is collected and dried at the end of the period. A set of bags containing fresh litter is then placed in the field for the next experimental period.

(3) A set of bags, placed in the field at the start of the experiment, is collected and dried at the end of each time period and replaced in the field for further measurements.

The first procedure is that conventionally used in litter-bag studies and yields one piece of information per time period per set of bags. The same set of $N$ bags yields $N$ pieces of information per time period if they are used as in the second or third techniques. This not only allows an error estimate of decomposition but also permits correlation of the individual readings with environmental parameters. To generate the same information using the first procedure would require $N$ sets of bags.

The second method is unacceptable because it does not allow decomposition measurements of a single litter increment with time, and it involves a much greater amount of work.

The third method is potentially more useful

but has two probable difficulties: repeated handling may result in significant spillage of litter (this is a potential problem in any litter bag study involving finely divided litter); and repeated artificial drying and rewetting may alter the rate of litter disappearance. The purpose of this paper is to examine these two problems and, where possible, to suggest remedial measures.

The relevant literature is reviewed below.

*Spillage*

Gilbert and Bocock (1962) questioned the advisability of using litter bags of small mesh size on the grounds that they might exclude larger solid fauna. Edwards and Heath (1963) tested this hypothesis and found that smaller meshes did indeed give lower rates of leaf disappearance. Most workers (e.g., Witkamp 1966; Gessner and Goos 1972) have since used large mesh sizes ranging from 0.5 mm to 1 cm. The authors have been unable to find spillage estimates in any of these papers, while the dearth of work on coniferous litter may reflect the practical difficulties of working with such finely divided material.

Witkamp (1966), using a 1-mm mesh, could only account for about 60% of the weight loss from litter bags by microbial decomposition. He attributed the discrepancy to loss by solid and liquid breakdown but did not mention any spillage. Bowes (personal communication) encountered considerable spillage in his litter decomposition study of an old-field community.

*Repeated Drying*

Repeated drying of organic matter has been shown to increase decomposition rates (Birch and Friend 1956; Winsor and Pollard 1956; Chase and Gray 1957; Birch 1958; Drobnik 1961; Witkamp 1966). These studies, most of which involved measurement of carbon dioxide evolution over several hours or days after re-

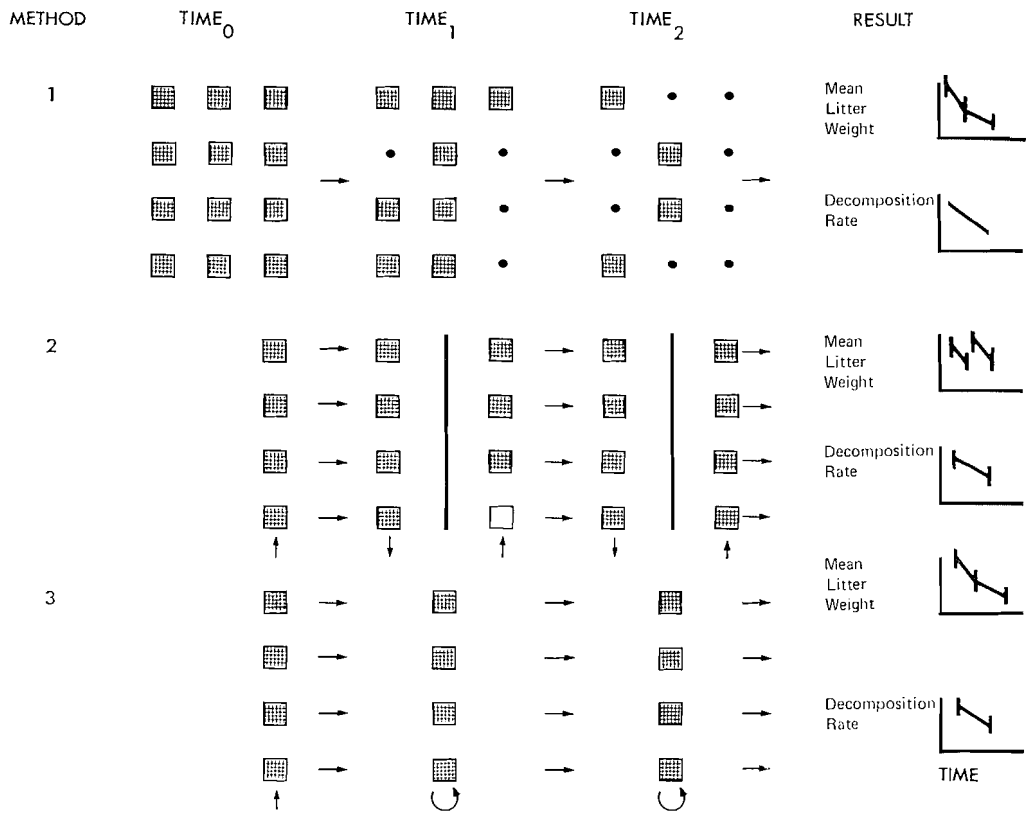


FIG. 1. Possible techniques for litter decomposition studies. See text for details of methods.

wetting, left the implication that the repeated drying and rewetting of litter bags may give overestimates of decomposition rates.

## Experiment to Determine the Amount of Spillage of Coniferous Litter from Litter Bags

*Materials and Methods*

The experimental plots were located on a newly cleared power line right-of-way 35 mi south of Sudbury, Ontario. The vegetation had been of white spruce (*Picea glauca* (Moench.) Voss.), jack pine (*Pinus banksiana* Lamb.), and red pine (*P. resinosa* Ait.) with an understory dominated by blueberry (*Vaccinium angustifolium* Ait.), bracken (*Pteridium aquilinium* (L.) Kuhn.), and sweetfern (*Myrica asplenifolia* L.). The coarse, sandy soil, where it was present, was up to 60 cm deep, highly podsolized, and underlain by granite. Initially the litter layer consisted mainly of conifer needles and the leaves of *Vaccinium* and *Pteridium*. Litter pH varied between 3.5 and 6.5. Two 25 m × 25 m plots are considered here, one of which was treated with Tordon 101 herbicide at a rate of 9.352 liters per hectare (1 U.S. gallon per acre) in July 1971.

Undecomposed litter was collected from the soil surface at 20 randomly chosen points on each plot. Amounts of fresh litter ranging from 10 to 20 g were placed in weighed nylon bags 10 cm × 14 cm, which were closed by folding over the open ends and securing each bag with three pins. Two bags of each of three mesh sizes (4 mm, 1 mm, 0.5 mm) were filled with litter from each point on the plots.

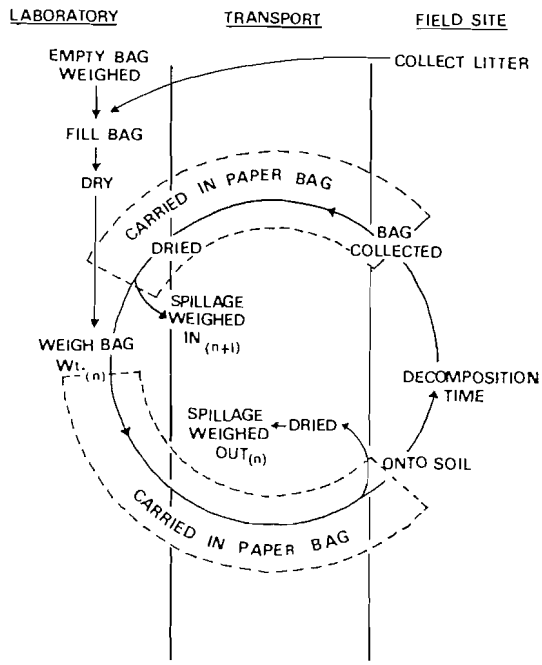


FIG. 2. The procedure used in determining spillage from litter bags. The notations in parentheses are referred to in the text.

The bags of litter were oven-dried for 48 h at 80°C and weighed. Each nylon bag was placed into a small paper bag immediately after weighing, and the spillage onto the balance pan was also tipped into the bag. The mesh bags were taken into the field in their paper bags and removed immediately before they were deposited on undisturbed litter at the appropriate point on the plot. Each bag was secured to the ground with three pieces of galvanized iron wire bent to form staples. Spillage into the paper bags was redried at 80°C for 24 h and weighed.

When they were returned to the laboratory, the litter bags were placed in paper bags immediately upon lifting them from the soil. The bags were dried for 48 h at 80°C and the nylon bags were removed from the paper bags only immediately before weighing. Weighing was carried out as on the first occasion, and the bags were returned to the field as before. The whole procedure is summarized in Fig. 2.

*Results and Discussion*

The largest mesh size was abandoned at the start of the experiment as spillage was excessive and could not be controlled. Percentage decomposition was calculated in two ways as follows (notation as in Fig. 1).

$$[1] \qquad U = \frac{\mathrm{Wt}_n - \mathrm{Wt}_{n+1}}{\mathrm{Wt}_n} \times 100$$

$$[2] \qquad C = \frac{\mathrm{Wt}_n - \mathrm{OUT}_n - (\mathrm{Wt}_{n+1} + \mathrm{IN}_{n+1})}{(\mathrm{Wt}_n - \mathrm{OUT}_n)} \times 100$$

where $U$ = uncorrected percentage decomposition;
$C$ = corrected percentage decomposition;
Wt = net weight at a given date;
OUT = spillage into paper bag on putting litter bag into field;
IN = spillage into paper bag on taking litter bag to laboratory from field;
subscript $n$ = date $n$; and
subscript $n+1$ = date $n+1$.

It will be noted that the spillage from the 1-mm mesh was only slightly greater than from the 0.5-mm mesh and that spillage is fairly constant for each mesh size (Fig. 3). The decomposition rate varies, however, with the season and the treatment so that the error associated with spillage rises with lower decomposition rates (Fig. 4), where the percentage error ($E$) is given by

$$[3] \qquad E = [(U - C)/C] \times 100.$$

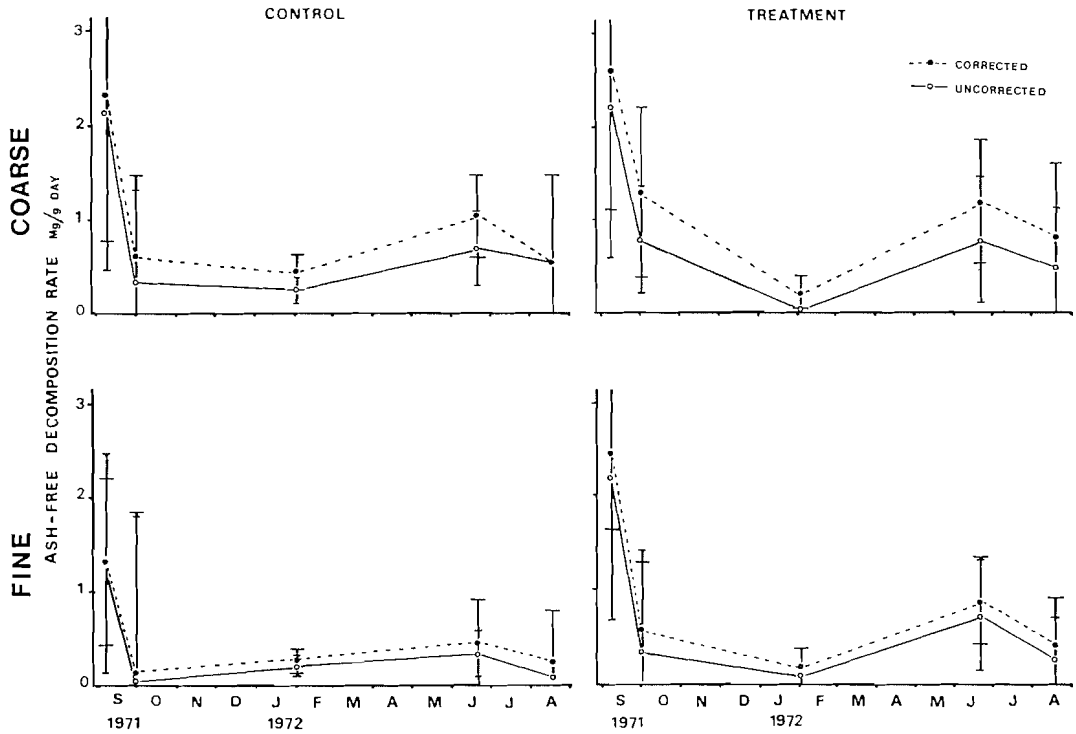


FIG. 3. Decomposition estimates using coarse (1-mm-) and fine (0.5-mm-) mesh bags calculated using 'corrected' and 'uncorrected' equations (see text). Results are shown for a control and a herbicide-treated plot.

Because of this relationship, estimates of decomposition may be much affected by spillage (Table 1), and if the decomposition period is brief or the rate of decomposition very low, the error may be quite significant. No comparison is made here between the herbicide treatment and control plot, as these will be considered in a further paper.

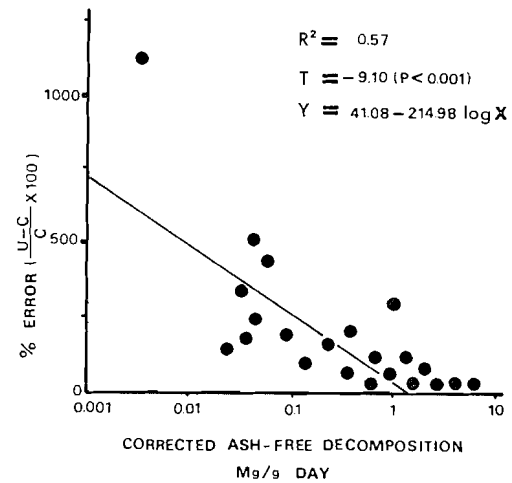


FIG. 4. The relationship between percentage error and corrected decomposition rate for coarse treatment bags; U, uncorrected decomposition; C, corrected decomposition. There are 65 points shown, but many overlap exactly.

The method outlined for the handling and transport of litter bags allows more precision in decomposition measurements by minimizing the error associated with spillage. It does involve more work, however, and careful thought should be given to use of the minimum size of mesh that will not inhibit decomposition. The difference between corrected and uncorrected decomposition rates is larger with a greater mesh size (Table 1). The expected maximum error due to spillage with a given mesh size may be estimated at the start of an experiment using a modified version of eq. 3:

$$EE = [(L/T)/D] \times 100$$

where $EE$ = expected percentage error;
$L$ = mean percentage spillage from a set

TABLE 1

Estimates of percentage decomposition from August 1971 to July 1972 using corrected and uncorrected data

| | Mean calculated decomposition, % | | Difference significant at ($t$ test for paired case): |
|---|---|---|---|
| | Uncorrected | Corrected | |
| Untreated plot | | | |
| 1-mm mesh | 24.74±11.48 | 17.88±12.45 | $P < 0.001$ |
| ½-mm mesh | 15.23± 3.52 | 12.83± 3.95 | $P < 0.02$ |
| Herbicide treated plot | | | |
| 1-mm mesh | 24.80±10.67 | 18.99± 8.0 | $P < 0.001$ |
| ½-mm mesh | 19.98± 7.11 | 14.51±10.59 | $P < 0.05$ |

of bags taken from the laboratory to the field and back;

$D$ = expected minimum daily decomposition percentage taken from the most similar previous study available; and

$T$ = expected time that bags will be in the field per time period (days).

## Experiment to Determine the Effects of Repeated Artificial Drying on Litter Decomposition Rates

*Methods*

One hundred nylon bags 10 × 14 cm and of 1-mm-mesh size were weighed and filled with well-mixed litter from an old-field site in the University of Guelph Arboretum, Guelph, Ontario. The site has been described in detail by Bradbury (1973). The material used consisted mainly of newly dead, dry leaves and stems of *Bromus inermis* Leyss. The filled bags were dried and reweighed, taken to the field site in paper bags, and pinned to the ground with galvanized iron wires. Five bags were placed in each of 20 contiguous quadrats 100 × 20 cm in an area dominated by *Bromus inermis*. The bags in each quadrat were assigned randomly to five groups, A, B, C, D, and E. The material that had fallen into the paper bags during transport was dried at 80°C and weighed.

TABLE 2

Summary of drying treatments

| Date dried* | Date put in field* | Treatments dried |
|---|---|---|
| — | 18/6/73 | A B C D E |
| 25/6/73 | 27/6/73 | A |
| 2/7/73 | 4/7/73 | A B |
| 10/7/73 | 12/7/73 | A C |
| 16/7/73 | 18/7/73 | A B |
| 23/7/73 | 25/7/73 | A |
| 30/7/73 | 1/8/73 | A B C D |
| 6/8/73 | 9/8/73 | A |
| 13/8/73 | 16/8/73 | A B |
| 20/8/73 | 22/8/73 | A C |
| 27/8/73 | 29/8/73 | A B |
| 4/9/73 | — | A B C D E |
| No. times litter dried, excluding last collection | | 11 6 4 2 1 |
| No. days litter in field | | 55 65 72 76 78 |

*Day, month, year.

At intervals some or all of the groups of bags were removed from the field in paper bags (Table 2), dried in the laboratory for 48 h at 80°C, and returned to the field in paper bags. Spillage was weighed as before. At the end of the experiment, 12 weeks after the nylon bags were first put out, they were all collected in paper bags, dried as before, and weighed.

*Results and Discussion*

The litter decomposition rates (Fig. 5) were calculated and expressed as decomposition per day as follows.

$$L = 1000\,[I - (F - S)]/I \cdot T$$

where $L$ = decomposition rate (mg/g day in the field);

$I$ = initial weight (g);

$F$ = final weight (g);

$S$ = total spillage (g); and

$T$ = total number of days bag is in field.

An analysis of variance showed that there was a significant difference ($P < 0.05$) between groups, but the results of a Student – Neumann – Keuls test (Table 3) did not consistently separate out those groups dried many times from those only dried once or twice. It is concluded that at the oven temperature used, which was deliberately made high in the hope of promoting a decomposition flush, redrying of old-field litter has little effect on decomposition estimates made using litter bags.

One possible source of inaccuracy is that decomposition might have been slowed initially after drying because of the dryness of the material in the bags. In his experiments, Birch (1958)

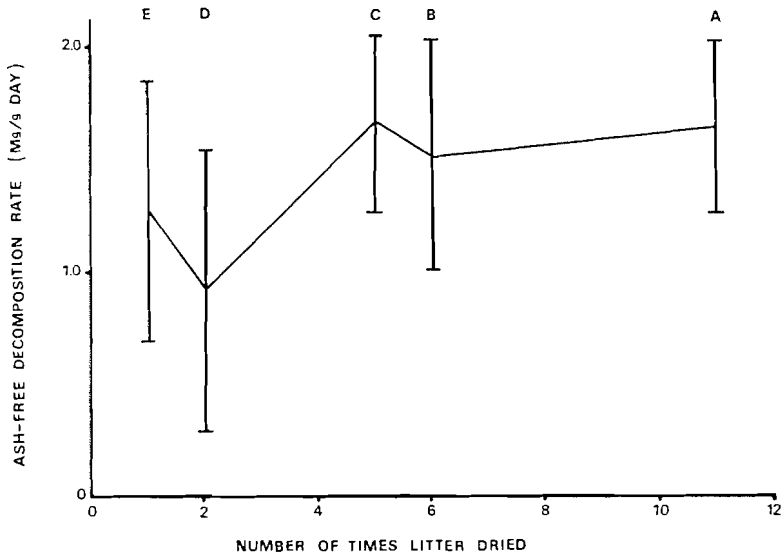


FIG. 5. The effect of repeated drying on apparent decomposition rates. Treatments referred to in Tables 2 and 3 are labelled A to E.

TABLE 3

Results of a Student–Neumann–Keuls test on five treatment means

| | Treatment | | | | |
|---|---|---|---|---|---|
| | A | B | C | E | D |
| No. times dried | 11 | 6 | 4 | 1 | 2 |
| Mean decomposition, mg/g day | 1.275 | 1.147 | 1.370 | 1.105 | 0.885 |
| | | | | * | |

*Solid line joining two means indicates no significant difference ($P < 0.05$).

rewetted his material artificially, thus promoting an immediate decomposition flush. It should be noted, however, that litter has not been rewetted after drying in any of the litter-bag studies reported in the literature (e.g., Witkamp 1966), except in aquatic studies (e.g., Gessner and Goos 1973). The authors hope to examine this possible source of error in further studies.

## Conclusions

It is concluded from the two experiments that spillage of litter can be a significant source of error in any litter-bag experiment if the litter is finely divided. This may account for unexplained losses by some workers (e.g., Witkamp 1966; Bowes, personal communication). It may also partially account for the finding of Edwards and Heath (1963) that decomposition rates are lower with smaller mesh sizes. It is apparent from the second experiment that artificial drying of old-field litter did not significantly alter decomposition rates. The method suggested in this report for measurement of litter decomposition rates is generally feasible in spite of earlier reports that drying and rewetting can increase decomposition rates (Birch 1958; Drobnik 1961).

BIRCH, H. G. 1958. The effect of soil drying on humus decomposition and nitrogen availability. Plant Soil, **10**: 9–31.

BIRCH, H. G., and M. T. FRIEND. 1956. The organic matter and nitrogen status of E. African soils. J. Soil Sci. **7**: 156.

BRADBURY, I. K. 1973. The strategy and tactics of *Solidago canadensis* L. in abandoned pasture. Ph.D. Thesis, University of Guelph, Guelph, Ontario.

CHASE, F. E., and P. H. GRAY. 1957. Application of the Warburg respirometer in studying respiratory activity in soil. Can. J. Microbiol. **3**: 335.

DROBNIK, J. 1961. Primary oxidation of some organic compounds in remoistened air-dried soil. Can. J. Microbiol. **7**: 769–777.

EDWARDS, C. A., and G. W. HEATH. 1963. The role of soil animals in breakdown of leaf material. *In* Soil

oganisms. *Edited by* J. Doeksen and J. Van Der Drift. North Holland, Amsterdam.

FALCONER, G. J., J. W. WRIGHT, and H. W. BEALL. 1933. The decomposition of certain types of forest litter under field conditions. Am. J. Bot. **20**: 196–203.

GESSNER, R. V., and R. D. GOOS. 1972. Fungi from decomposing *Spartina alterniflora*. Can. J. Bot. **51**: 51–55.

GILBERT, O. J., and K. L. BOCOCK. 1958. The disappearance of leaf litter under different woodland conditions. Plant Soil, **9**: 179–185.

——— 1962. Some methods of studying the disappearance and decomposition of leaf litter. *In* Progress in soil zoology. *Edited by* P.W. Murphy. Butterworths, London.

GUSTAFSON, F. G. 1943. Decomposition of the leaves of some forest trees under field conditions. Plant Physiol. **18**: 704–707.

LOMNICKI, A., E. BANDOLA, and K. JANKOWSKA. 1968. Modification of the Wiegart–Evans method for estimation of net primary production. Ecology, **49**: 147–149.

LUNT, H. A. 1935. Effect of weathering upon dry matter and composition of hardwood leaves. J. For. **33**: 607–609.

MALDAGUE, M. E. 1967. Vitesse de décomposition de différent types de Litières forestières. *In* Progress in soil biology. *Edited by* O. Graff and J. E. Satchell. North Holland, Amsterdam.

MIKOLA, P. 1955. Koeellisia tutkimuksia metsakarikkeiden hajaartumisnopeudesta. Commun. Inst. For. Fenn. **43**: 1–50.

NOMMICK, A. 1938. Uber die Zersetzungsgeschwindigkeit des gefallenen Laubes und der Koniferennadeln und uber den Schwind einiger in ihnen enthaltenen Elemente. Bodenk. Pflanzenerhaehr. **8**: 77–100.

WIEGART, R. G., and F. C. EVANS. 1964. Primary production and the disappearance of dead vegetation in an old field in southeastern Michigan. Ecology, **45**: 49–63.

WINSOR, G. W., and A. G. POLLARD. 1965. Carbon–nitrogen relationships in soil. IV. Mineralisation of carbon and nitrogen. J. Sci. Food Agric. **7**: 618.

WITKAMP, M. 1966. Decomposition of leaf litter in relation to environment, microflora, and microbial respiration. Ecology, **47**: 194–201.

WITTICH, W. 1939. Untersuchungen uber den Verlauf der Streuzersetung auf einen Boden mit Mullzustand. Forstarchiv. **15**: 96–111.